VALIDATION OF ADVANCED FLIGHT SIMULATORS FOR OPERATIONAL EVALUATION AND TRAINING PROGRAMS

OCTOBER 12, 2002

Briefing prepared by:
Dr. A. E. Dillard
Federal Aviation Administration
National Resource Specialist, Simulation Engineering, AFS-408

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Definitions:**
  - **Simulator – A flight training device with full six-degree of freedom motion system, a visual system that meets FAA Level D requirements and meets performance standards of AC 120-40.**
  - **Operational Evaluation Program – Test programs to support operational or equipment approval conducted in a realistic operational environment using advanced flight simulators**
  - **Aircraft Data Base – Aircraft performance data base representing flight test data from the aircraft manufacturer**
  - **Simulator Approval – Granting approval or certification for a simulator device meeting the requirements of FAA AC 120-40 or ICAO equivalent.**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Types of Simulation**
  - **Full Flight Simulators – Levels A thru D**
  - **Training Devices – Levels 1 thru 7**
  - **Part Task Simulators**
  - **Laboratory Simulators**
  - **Unmanned Integrated Modeling**
  - **Mathematical Modeling**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **History of Flight Simulators**
  - **World War II**
  - **Application to Civilian Pilot Training**
  - **Development of Computers**
  - **Development of Motion Bases**
  - **Development Of Visual Systems**
  - **Advanced Simulator Program in 1970s**
  - **Application of Actual Aircraft Performance Data Bases**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Uses of Full Flight Simulators**
  - **Advanced Training Program**
    - **Level A thru D**
    - **Level D requires no Aircraft flight time for transition training with approved training program**
    - **Aircraft and systems modeling to highest level of fidelity possible – no effort to model pilot**
    - **Attributes – Discussion**
    - **Operation Evaluation Programs**
    - **Networking**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Simulator Costs**
  - **Approximately $14M for Level D Device**
    - **Includes:**
      - **Spares**
      - **Training**
      - **Tolls and Test Equipment**
      - **Instructors/Operators Facilities**
      - **HLA/DIS Compatible**
      - **Delivery/Installation/Certification**
      - **Warranty**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Issues for Using Simulators for Operational Evaluation Programs**
  - **Flight performance fidelity through-out flight envelope under test**
  - **Systems Fidelity**
  - **Realistic environmental conditions**
  - **Realistic faults/failures**
  - **Realistic operating environment**
  - **Realistic pilot workload**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Primary drivers for operational evaluation programs**
  - **New equipment certification and operational approval**
  - **New procedures – closely spaced runways, land and hold short, increased system through-put**
  - **New Air traffic procedures and rules**
  - **New airport design and infrastructure**
  - **Testing for operating environment phenomena**

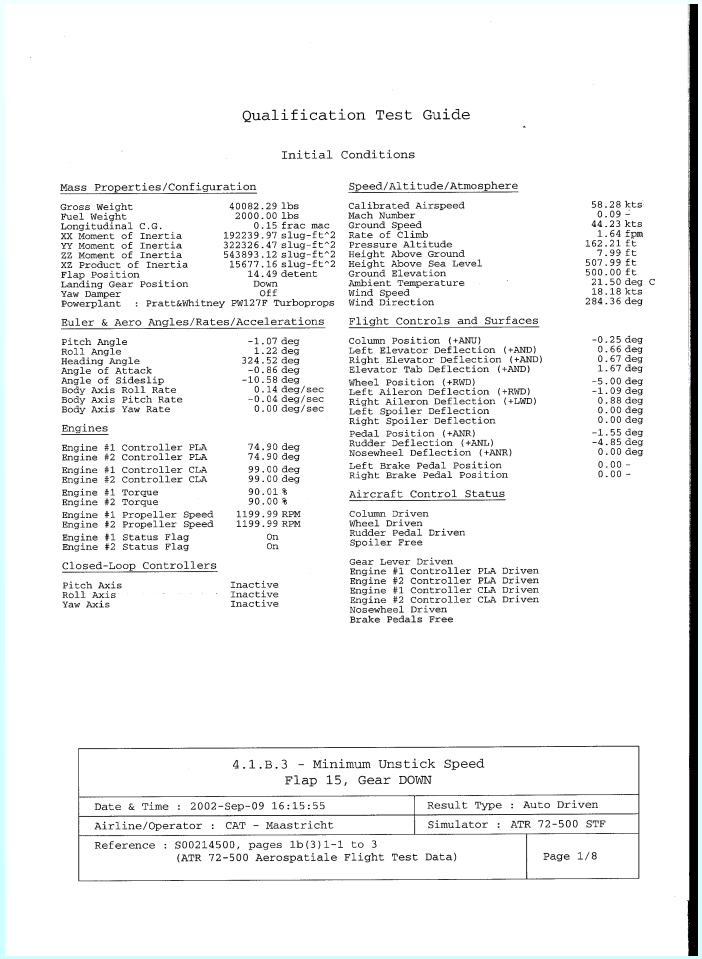
VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Pilots as test subjects**
  - **System is set up to define minimum pilot performance requirements**
  - **Highly trained and retrained**
  - **Select group – changing in civil world**
  - **Cadre of pilot test subjects must be representative of pilot population at large – age distribution, current in aircraft type, line pilot.**
  - **Active to age 60 – then forced to retire under current law**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Validation of aircraft flight performance**
  - **Advanced simulator program ensures performance against known aircraft data**
  - **Confirmed by objective comparison of plotted performance variables plus expert subjective testing**
  - **Advanced simulators checked twice annually against selected maneuvers**
  - **Includes visual, motion and through-put/latency testing**

VALIDATION OF ADVANCED FLIGHT SIMULATORS



Qualification Test Guide

Initial Conditions

Mass Properties/Configuration

Gross Weight	40082.29 lbs
Fuel Weight	2000.00 lbs
Longitudinal C.G.	0.15 frac mac
XX Moment of Inertia	192239.97 slug-ft^2
YY Moment of Inertia	322326.47 slug-ft^2
ZZ Moment of Inertia	543893.12 slug-ft^2
XZ Product of Inertia	15677.16 slug-ft^2
Flap Position	14.49 detent
Landing Gear Position	Down
Yaw Damper	Off
Powerplant : Pratt&Whitney PW127F Turboprops	

Euler & Aero Angles/Rates/Accelerations

Pitch Angle	-1.07 deg
Roll Angle	1.22 deg
Heading Angle	324.52 deg
Angle of Attack	-0.86 deg
Angle of Sideslip	-10.58 deg
Body Axis Roll Rate	0.14 deg/sec
Body Axis Pitch Rate	-0.04 deg/sec
Body Axis Yaw Rate	0.00 deg/sec

Engines

Engine #1 Controller PLA	74.90 deg
Engine #2 Controller PLA	74.90 deg
Engine #1 Controller CLA	99.00 deg
Engine #2 Controller CLA	99.00 deg
Engine #1 Torque	90.01 %
Engine #2 Torque	90.00 %
Engine #1 Propeller Speed	1199.99 RPM
Engine #2 Propeller Speed	1199.99 RPM
Engine #1 Status Flag	On
Engine #2 Status Flag	On

Closed-Loop Controllers

Pitch Axis	Inactive
Roll Axis	Inactive
Yaw Axis	Inactive

Speed/Altitude/Atmosphere

Calibrated Airspeed	58.28 kts
Mach Number	0.09 -
Ground Speed	44.23 kts
Rate of Climb	1.64 fpm
Pressure Altitude	162.21 ft
Height Above Ground	7.99 ft
Height Above Sea Level	507.99 ft
Ground Elevation	500.00 ft
Ambient Temperature	21.50 deg C
Wind Speed	18.18 kts
Wind Direction	284.36 deg

Flight Controls and Surfaces

Column Position (+ANU)	-0.25 deg
Left Elevator Deflection (+AND)	0.66 deg
Right Elevator Deflection (+AND)	0.67 deg
Elevator Tab Deflection (+AND)	1.67 deg
Wheel Position (+RWD)	-5.00 deg
Left Aileron Deflection (+RWD)	-1.09 deg
Right Aileron Deflection (+LWD)	0.88 deg
Left Spoiler Deflection	0.00 deg
Right Spoiler Deflection	0.00 deg
Pedal Position (+ANR)	-1.55 deg
Rudder Deflection (+ANL)	-4.85 deg
Nosewheel Deflection (+ANR)	0.00 deg
Left Brake Pedal Position	0.00 -
Right Brake Pedal Position	0.00 -

Aircraft Control Status

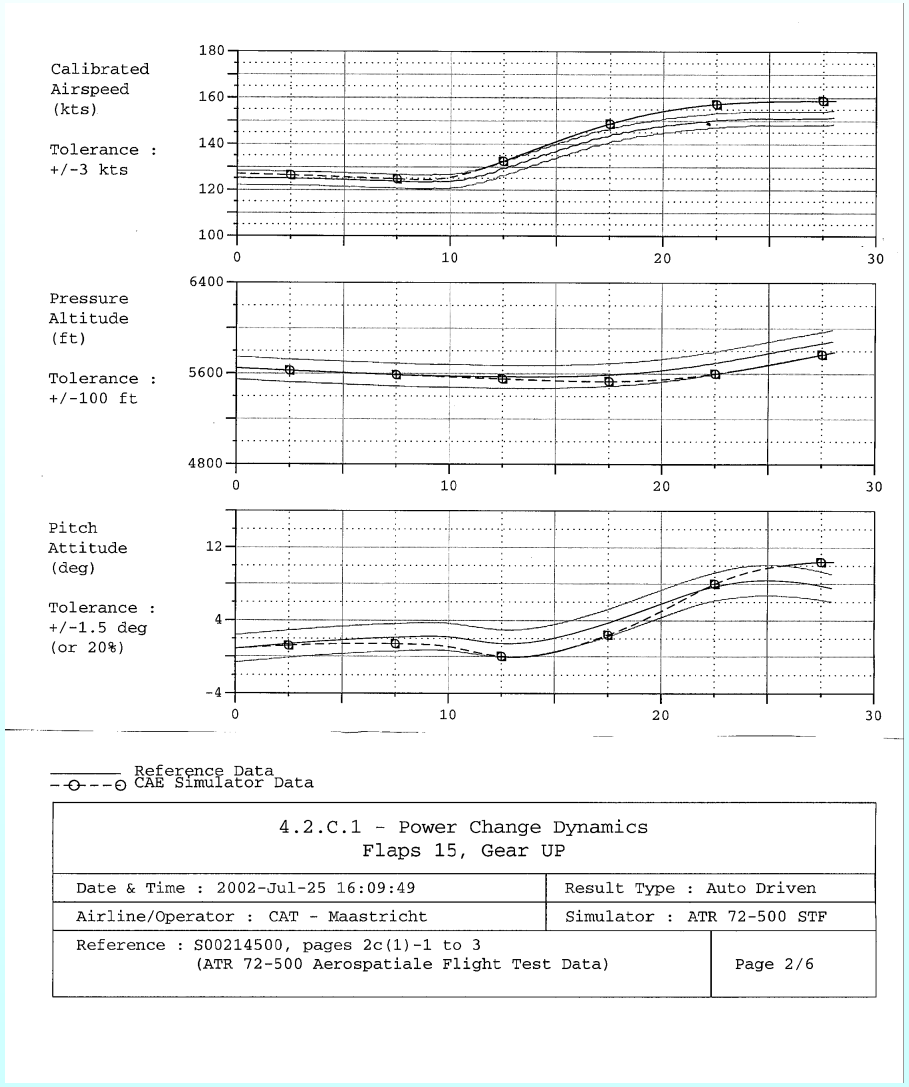
Column Driven
Wheel Driven
Rudder Pedal Driven
Spoiler Free

Gear Lever Driven
Engine #1 Controller PLA Driven
Engine #2 Controller PLA Driven
Engine #1 Controller CLA Driven
Engine #2 Controller CLA Driven
Nosewheel Driven
Brake Pedals Free

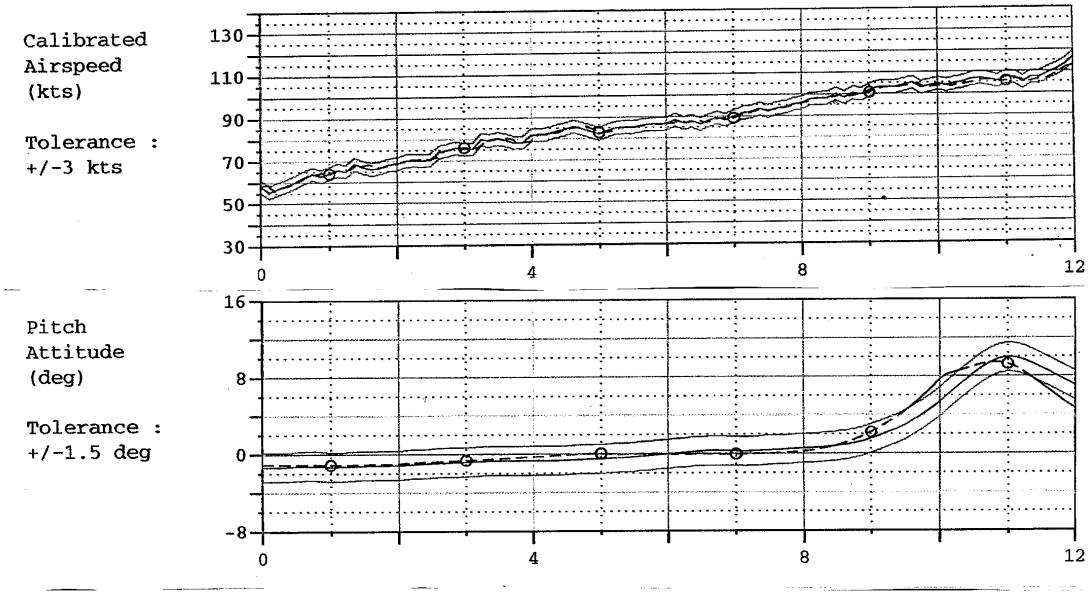
4.1.B.3 - Minimum Unstick Speed
Flap 15, Gear DOWN

Date & Time : 2002-Sep-09 16:15:55	Result Type : Auto Driven
Airline/Operator : CAT - Maastricht	Simulator : ATR 72-500 STF
Reference : S00214500, pages 1b(3)1-1 to 3 (ATR 72-500 Aerospatiale Flight Test Data)	Page 1/8

VALIDATION OFADVANCED FLIGHT SIMULATORS



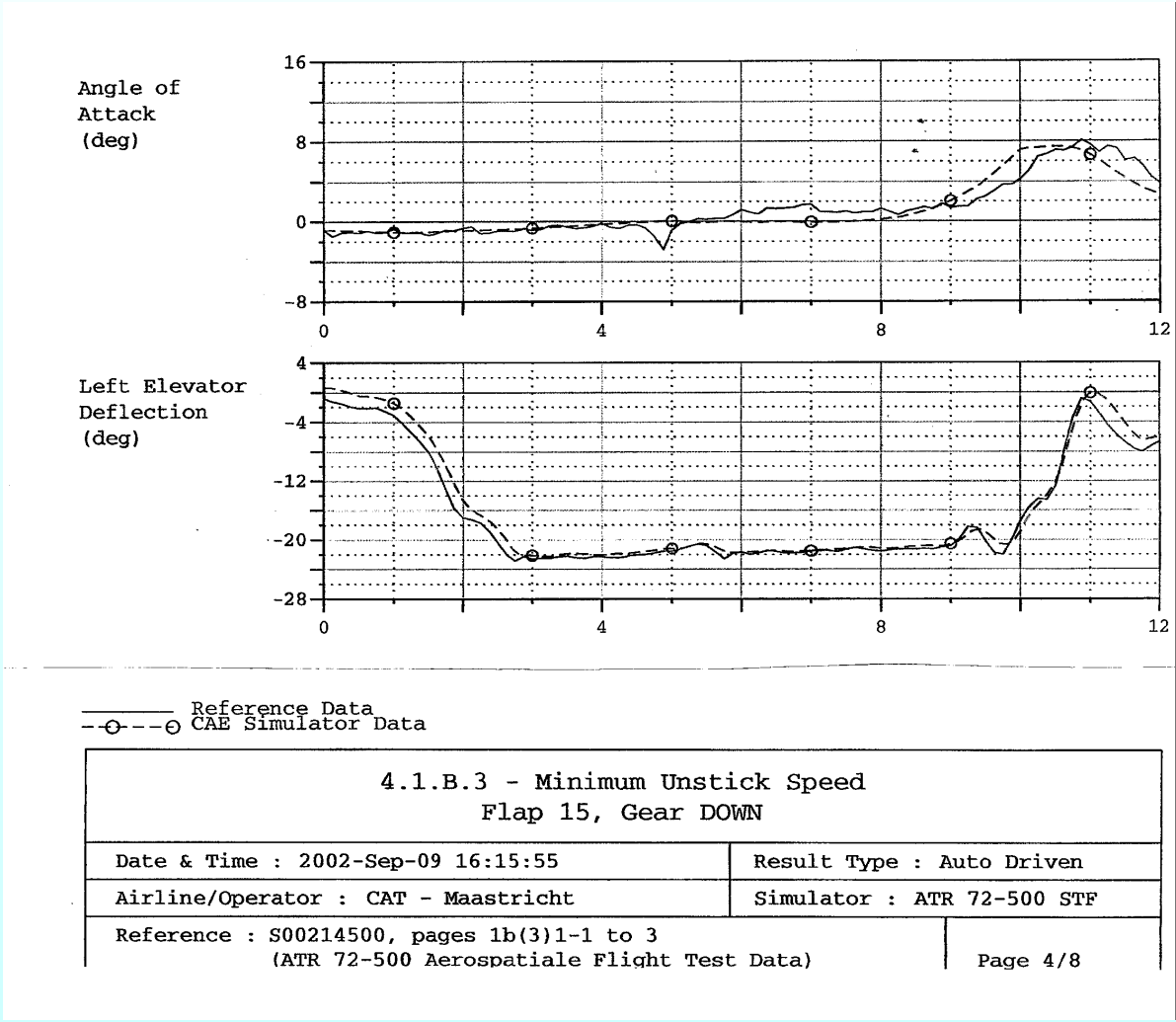
VALIDATION OFADVANCED FLIGHT SIMULATORS



Reference Data
CAE Simulator Data

4.1.B.3 - Minimum Unstick Speed Flap 15, Gear DOWN	
Date & Time : 2002-Sep-09 16:15:55	Result Type : Auto Driven
Airline/Operator : CAT - Maastricht	Simulator : ATR 72-500 STF
Reference : S00214500, pages 1b(3)1-1 to 3 (ATR 72-500 Aerospatiale Flight Test Data)	Page 3/8

VALIDATION OF ADVANCED FLIGHT SIMULATORS



VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Systems Validation**
  - **Navigation performance tested as part of approval process against terminal area geographical data base (Runway positioning and visual scene)**
  - **On commercial simulators you must confirm en-route geo positioning**
  - **Must validate specific system fidelity if critical to current evaluation**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **System Modeling**
  - **Uses actual equipment manufacturers design data**
  - **Emulation (uses actual aircraft display software with non-airworthy hardware) of flight deck displays preferred to simulated instruments if actual aircraft hardware not used.**
  - **May need to develop test plan to test specific critical systems**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Distributed Interactive Simulation**
  - **Commercial simulators generally not HLA compliant**
  - **Much less data typically transferred than with military DIS**
  - **Simulators manufactured to different hardware specs**
  - **Extremely price competitive – Hence, few bells and whistles**
  - **Little interest for normal training requirements**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Typical Operational evaluation programs**
  - **Low visibility operations**
  - **New technology**
  - **New procedures**
  - **Airport Infrastructure**
  - **New airport designs**
  - **Navigation**
  - **Communications**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Analysis of results**
  - **Collect data on critical performance variables**
    - **Attitude**
    - **Airspeed**
    - **Altitude**
    - **Three dimensional track data (X, Y, Z or Lat/Long)**
    - **Monitor for pilot actions**
    - **Video**
    - **Audio**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Advantages of using advanced flight simulators**
  - **Collaborative research environment**
  - **High fidelity operational environment**
  - **Low risk to equipment and personnel**
  - **Mush cheaper than actual aircraft**
  - **Better control of test environment**
  - **Scenario repeatability**
  - **Equipment availability**
  - **Ability to modify and manipulate system performance through software**
  - **Ability to network**
  - **Data collection capabilities**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Disadvantages of using approved advanced simulators**
  - **Cheaper than aircraft but still costly ($300 to $1200 flight hour**
  - **Limited availability**
  - **Requires expert technical support**
  - **Can require special system validation**
  - **Changes to hardware and software on approved simulators cannot affect approved performance or equipment configuration**
  - **Must compete with training programs for time**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

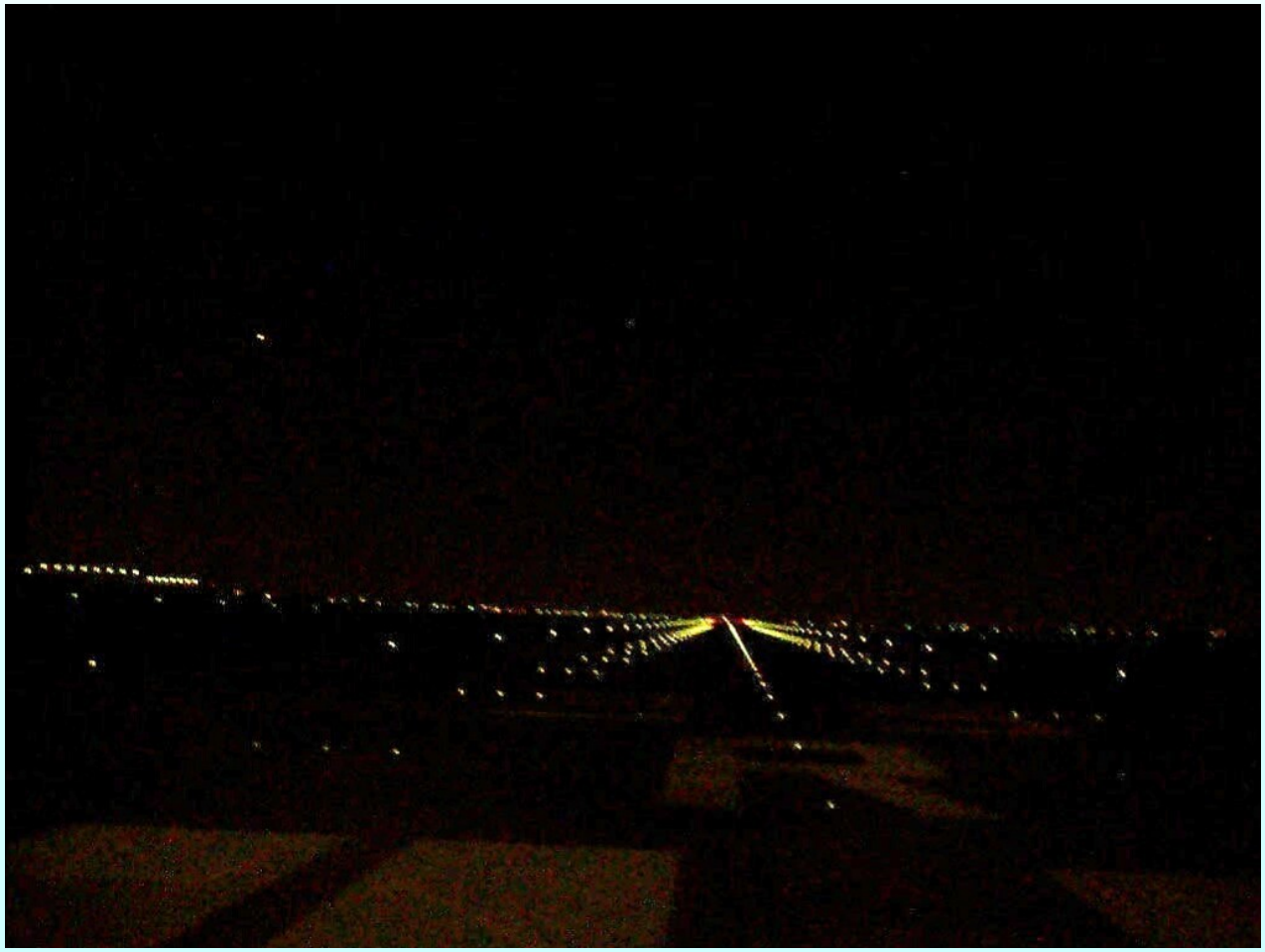
- **Examples of a recent program**
  - **Laser Visual Interference**
    - **Worked with Brooks AFB Labs, FDA, Others**
    - **Worked with Laser industry**
    - **Supported by SAE G-10 HBET Committee to provide technical oversight and expert guidance**
    - **Used live laser coupled via fiber optic cable to cockpit**
    - **Illuminated pilot at critical junctures in typical flight operations in the terminal airspace**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Laser – Continued**
  - **Approximately 40 pilots tested**
  - **Three levels of exposure**
- **Results**
  - **New standards for use of lasers in commercial airspace**
  - **New Advisory Circular for education of FAA and pilot community**
  - **Used to develop new international (ICAO) standards**

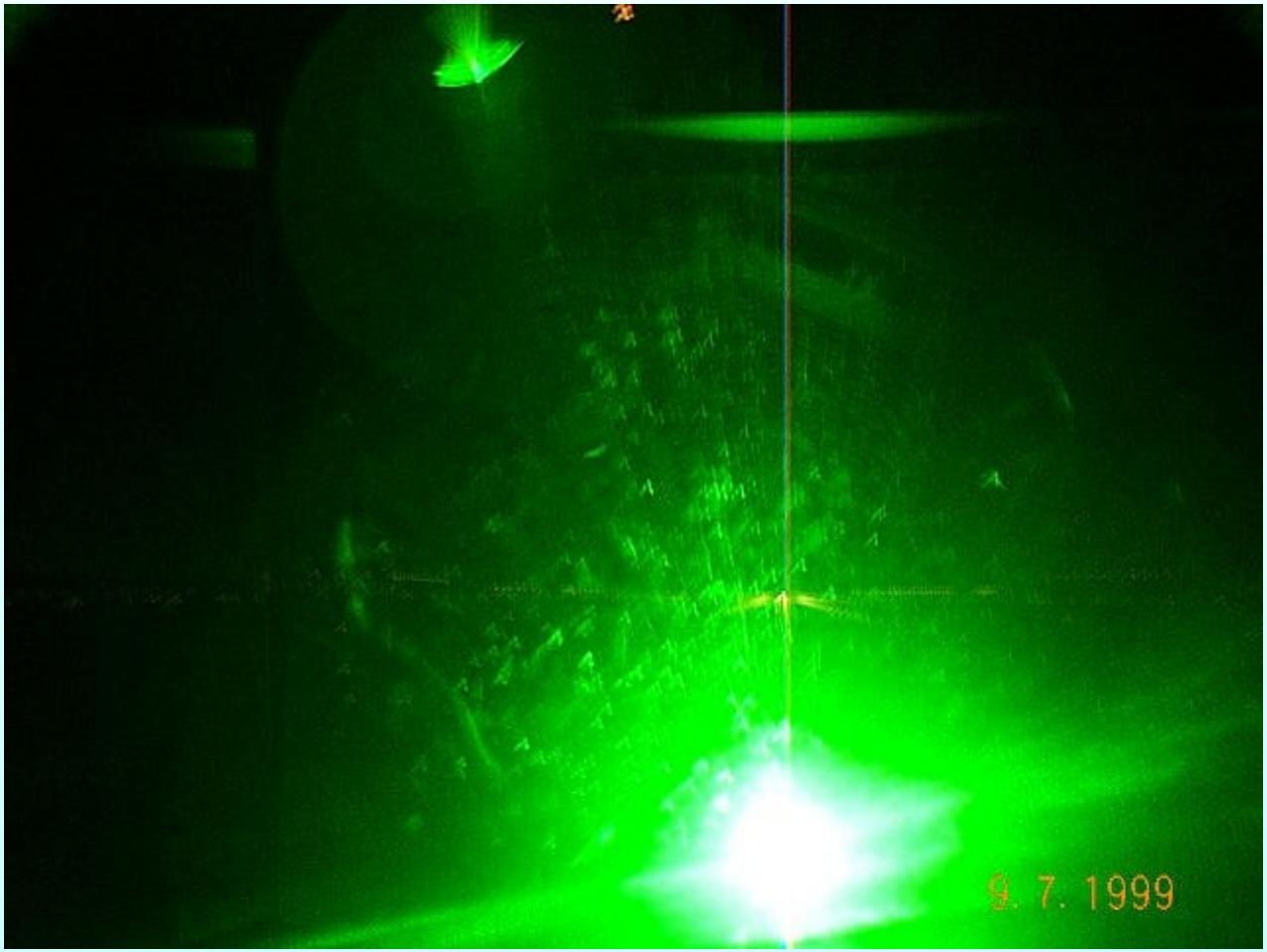
VALIDATION OF ADVANCED FLIGHT SIMULATORS

VALIDATION OF ADVANCED FLIGHT SIMULATORS

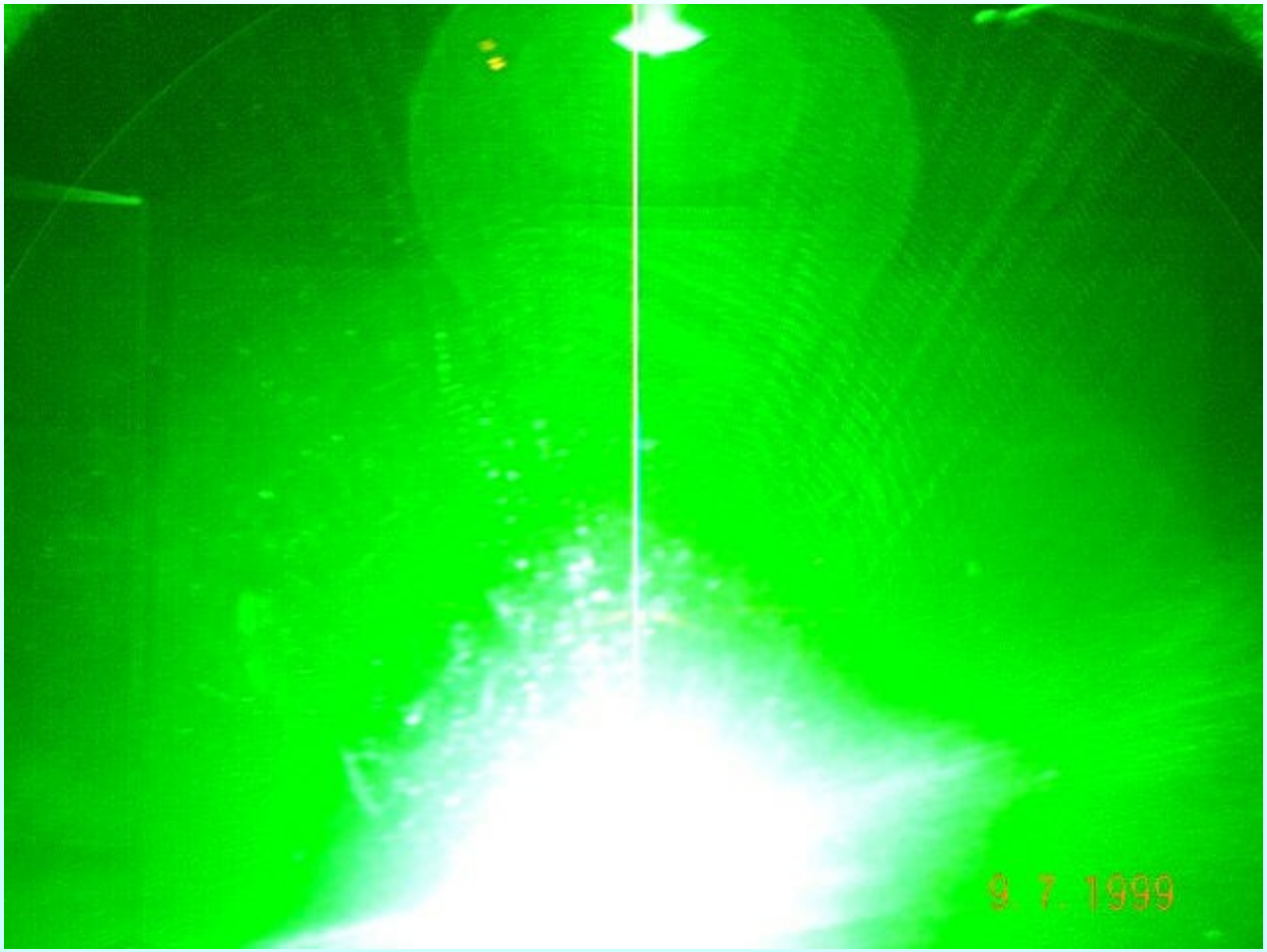


VALIDATION OF ADVANCED FLIGHT SIMULATORS

VALIDATION OF ADVANCED FLIGHT SIMULATORS



VALIDATION OF ADVANCED FLIGHT SIMULATORS



VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **New Technology on the Flight Deck**
  - **Head-Up Display**
  - **Cockpit display of traffic information**
  - **Multi-function displays**
  - **ADS-B**
  - **Data link communications**
  - **Hazard avoidance/detection**
  - **Navigation – GPS, LAAS, WAAS**
  - **Communications**
  - **Fly-by-wire technology**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Airport Design and Infrastructure**
  - **New Denver Airport**
  - **Approach lighting**
  - **High-speed exits**
  - **Markings and signage**
  - **Land and Hold Short operations**
  - **Runway incursions**
  - **Contaminated runways**
  - **Over-run protection**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Environmental Phenomena**
  - **Wake Vortex**
  - **Icing**
  - **Unusual attitudes**
  - **Low visibility operations**
  - **Wind shear detection and recovery**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Summary –**
  - **Open, collaborative test environment**
  - **Enhanced data collection capabilities**
  - **Serve as a bridge between the laboratory and the aircraft**
  - **Widely distributed geographically**
  - **Lower risk than using actual aircraft**
  - **Repeatability**

VALIDATION OF ADVANCED FLIGHT SIMULATORS

- **Summary - Continued**
  - **Advanced simulators available for virtually all commercial aircraft**
  - **More cost effective than using actual aircraft**
  - **Lower operating cost - $300 to $1200/hr, than actual aircraft (Typically 1/10 th the cost)**
  - **Offer a high fidelity, realistic operating environment**
  - **Able to modify software and hardware within defined constraints**